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# An analog display system for digital graph plot output

Donohue, Douglas J.

Monterey, California; Naval Postgraduate School

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AN ANALOG DISPLAY SYSTEM  
FOR DIGITAL GRAPH PLOT OUTPUT

DOUGLAS J. DONOHUE

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AN ANALOG DISPLAY SYSTEM  
FOR DIGITAL GRAPH PLOT OUTPUT

\* \* \* \* \*

Douglas J. Donohue





AN ANALOG DISPLAY SYSTEM  
FOR DIGITAL GRAPH PLOT OUTPUT

by

Douglas J. Donohue  
//  
Lieutenant, United States Navy

Submitted in partial fulfillment of  
the requirements for the degree of

MASTER OF SCIENCE  
IN  
ELECTRICAL ENGINEERING

United States Naval Postgraduate School  
Monterey, California

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the Status of the  
American Indian

Committee on the Status of the  
American Indian

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AN ANALOG DISPLAY SYSTEM  
FOR DIGITAL GRAPH PLOT OUTPUT

by

Douglas J. Donohue  
Lieutenant, United States Navy

This work is accepted as fulfilling  
the thesis requirements for the degree of

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## ABSTRACT

Two versions of an analog display program have been assembled for the analog display of digitally derived graph plot information. Input to the analog display system is the magnetic tape output by the "DRAW" subroutine used at the U. S. Naval Postgraduate School Computer Facility. The fast version of the program, driving an oscilloscope as the display element, provides a clear and accurate display of the graph points, but is of limited usefulness due to the small size of the standard scope face and the flicker in the presentation. The slow version, employing an x-y plotter as the display element, also yields an adequate display, and at a slightly faster rate than the existing digital plotter currently used by the Computer Facility for graphical output. A linear interpolation routine has been implemented in the slow version, so that plotter response is not affected by coarseness in the data points.



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## TABLE OF SYMBOLS AND ABBREVIATIONS

CDC	Control Data Corporation
MTU	Magnetic tape unit
D/A	Digital to analog
DRAW	A library subroutine in the CDC 1604 FORTRAN system that provides for output of graph plots.
BCD	Binary coded decimal



## 1. Introduction.

With the increasing use of the CDC 1604 computer at the Naval Postgraduate School, the time required for the printing of graph plot output by the present off-line system has become an item for concern. The time required for the present equipment combination (CDC 160, CDC 163, and CAL-COMP digital plotter) to complete one graph is usually two to three minutes, thereby limiting the system's output to approximately 20 graphs per hour. By assuming that six hours of CDC 160 time is available for graph plotting, and that the average user requests three graphs, the conclusion is reached that 40 users could saturate the capability of the existing system. These figures point to the desirability of developing a faster graph plotting system.

### 1.1 Project definition.

This project was undertaken to investigate the feasibility of off-line analog display of graph plot information, with the major emphasis on the associated CDC 160 programming effort. More specifically, the objective was to generate the CDC 160 programming necessary to display the digital graph data on a cathode ray tube device for direct viewing or photo-copying.

### 1.2 Basic assumptions.

The analog display program was written within the framework of the following assumptions:

- a. The only equipment available to the project was that already present at the Naval Postgraduate School.
- b. The specially prepared magnetic tape generated by the "DRAW" subroutine was to be used as the input to the analog display system.



c. The number of cells needed for the CDC 160 program should be as few as possible in order to leave maximum room for graph plot information in the computer's memory. As a goal, one-quarter of the memory was allocated to the program.

d. Refinements, such as curve and ordinate labelling, and variable character sizes were considered unessential to the project.

### 1.3 The analog display system.

A block diagram of the analog display system is shown in figure 1. The tasks assigned to the various elements of the system are as indicated below:

a. The CDC 163 magnetic tape unit provides the input data to the CDC 160 digital computer from a specially prepared magnetic tape. Data format for the tape is described in Appendix 1.

b. The CDC 160 digital computer reads the graph plot data from the magnetic tape as needed, transforms and stores this data in the format required by the digital to analog (D/A) conversion equipment, and then outputs this transformed data to the conversion equipment in the sequence required for a meaningful presentation.

c. The digital to analog (D/A) conversion equipment converts each twelve bit word output by the computer into an analog voltage.

d. The display element provides a visible trace of the analog voltages output by the D/A conversion equipment.





## 2. Computer programming.

The digital computer tasks were divided into separate routines as listed in figure 2. All of these routines were written in relocatable form except as noted.

### 2.1 ZEST routine.

Operation of the analog display system program is controlled by this routine. The list of acceptable starting addresses and their functions is given in figure 3. The routine exists to the routine labelled "ROT".

### 2.2 ROT routine.

This routine controls the display sequencing of titles, origin, and graph points by employing subroutines and simple parameter manipulations. The routine is an endless loop and will continue to cause the display of graph plot information in the absence of operator interruption or equipment malfunction.

### 2.3 READ subroutine.

The main elements in the operation of the READ subroutine are listed below: (fixed location - 1530-1741) .

- a. Read and store the number of title lines.
- b. Clear title memory space to permit the subsequent search for the last character of a title line.
- c. Read and store one title line.
- d. Find the address of the last BCD character in the title line that is not a space or 00 code.
- e. Add the title line end code (77) as the last character of the title line.
- f. Pack the title line into the memory file, two BCD characters per computer word.



- g. Index the file pointing cells.
- h. Return to item b. for next title line. Continue if no title lines remain to be processed.
- i. Read the location of the origin of the graph plot, transform this location to the form required for display, and store in computer memory.

#### 2.4 GREAD subroutine.

The reading and transformation of the graph points generated by the "DRAW" routine is controlled by the GREAD subroutine. The main elements are described below:

- a. Store the number of curves to be displayed and set the file pointing cells.
- b. Transform (i.e. relocate the origin and change the scale of) the graph points to a form suitable for display. The required transformation is described in Appendix II.
- c. Index the file pointing cells.
- d. Return to item b. for next curve. Continue if all curves have been processed.
- e. If the number of graph points exceeds the available memory space, GREAD will reduce the number of curves requested by one, reset the magnetic tape to restart the current graph plot and halt in 0007. Run to continue.

#### 2.5 TAP subroutine.

The Tap subroutine is a general-purpose read/write routine for the control of the CDC 163 magnetic tape unit.

#### 2.6 LTR subroutine.



This routine outputs the necessary computer instructions to the D/A conversion equipment to form the analog representations of the BCD characters stored in memory. Each letter is drawn by forming a series of closely spaced voltages so that a nearly continuous series of dots is displayed on the oscilloscope. Individual movement codes for character generation are recovered from the character table by employment of the RNC subroutine. The LTR subroutine is divided into the sections described below:

- a. Output the first point of the line in the pen up mode.
- b. Pickup the BCD character from memory. If an end of line code (77) is detected, go to item g.
- c. Consult the character table to determine the location of the appropriate movement codes.
- d. Pickup the movement code from memory and decode it for pen control, direction, number of steps, and step size information. Each movement code contains horizontal or vertical information only. If an end of letter code (77) is detected, go to item b.
- e. Output motion in one direction.
- f. Set arguments for motion in the other direction and return to item d.
- g. Line complete; exit.

## 2.7 RNC subroutine.

The RNC routine reads six bit bytes from a file of two six bit words per computer word into the arithmetic register. File tracking is performed by a file pointer and a half-word pointer set in low core memory.





## 2.8 Character table.

The first portion of the Character table (cells 1000-1077) contains the memory location of the initial movement codes for a specified BCD character.

The second portion (cells 1100-1527) contains the movement codes used by the LTR subroutine in generating the characters of the title line. Each movement code is a six bit word which contains information for horizontal or vertical motion only. The four least significant bits of the movement code contain the number of required steps in one direction, the most significant bit sets the direction in a positive or negative sense, and the remaining bit sets the step size. Special movement codes are octal 77, 76, and 75. These codes indicate the end of a character, set the pen up (blank), and set the pen down (unblank) respectively. The horizontal and vertical movement codes alternate in the table and the first code in the table (and the first code after a special code) is a horizontal movement code.

## 2.9 GRP subroutine.

This routine takes the contents of the specially prepared graph point file in the computer memory and provides the necessary output instructions to cause the D/A conversion equipment to output corresponding voltages for display. The graph point file has a 24 bit word length; the most significant 12 bits indicating the horizontal ordinate and the least significant 12 bits (in the computer word) indicating the vertical ordinate of the graph point. The file beginning and file end memory locations and a file pointing cell are set in low core memory.





## 2.10 DA and LDA subroutines.

These delay subroutines are used to slow the computation to match the characteristics of an x-y plotter display element. The DA routine counts to octal 1000 to generate a delay of approximately 6.5 milliseconds. The LDA routine repeats the DA routine N times, where N is the entry argument.



### 3. Discussion of results.

Two versions of the analog display program have been written; a fast version which uses an oscilloscope as the display element; and a slow version for use with an x-y plotter. The slow version is essentially a delayed version of the fast program with other variations for more refined pen control and sequencing needed when printing a continuous hard copy. Both versions occupy approximately one-quarter of the computer memory.

#### 3.1 Fast version with oscilloscope display element.

The graph plot display provided by the oscilloscope was clear and accurate, but testing has shown that the fast program for direct viewing of the scope is not fast enough to prevent flicker. Flicker is particularly noticeable in the title line display, and to a reduced degree in the graph point display. Approximately six characters or 400 graph points can be displayed without the appearance of flicker, but since a normal title contains approximately 90 characters, a twenty to one improvement in cycle time is needed. This improvement is unattainable without a change in equipment; a computer with a faster memory or a larger memory, or both. A trade off is possible between the speed of operation and computer memory space, but the needed improvement is beyond the capabilities of the computer used. Some improvement could be made in display quality by employing an oscilloscope with a long persistence phosphor on the screen of the cathode ray tube. A memscope was tried as the display element, but the particular model used was unsatisfactory due to lack of resolution and inadequate horizontal gain. Another approach would be to use coded titles, thus decreasing the time required for title display.



Since the oscilloscope displays a series of dots corresponding to the discrete voltages output by the D/A conversion equipment rather than a continuous line, some provision must be made for the blanking of the unwanted dots as the trace moves from graph point to graph point. Two steps are needed in moving from one point  $(x_0, y_0)$  to the next point  $(x_1, y_1)$  not on a horizontal or vertical line from the first point. Motion is output first in the horizontal direction to a temporary point  $(x_1, y_0)$  followed by a vertical move to the desired point  $(x_1, y_1)$ . It is the intermediate point that must be blanked to provide an uncluttered display. A similar situation requiring blanking exists in the spacing between letters in the title lines. The necessary blanking is attained by employment of the "AND" gate described in Appendix II, and shown in figure 5.

The effective viewing area of the standard oscilloscope cathode ray tube is a square of approximately three inches on a side. This is not adequate for the display of readable titling together with a graph of acceptable size. A large DuMont slave oscillograph was considered, but it lacked the requisite frequency response for suitable display characteristics.

For direct viewing, no provision is made for the retention of the scale grid in the display of the second and subsequent curves of a multi-curve graph. Since the "DRAW" routine treats the scale grid simply as two separate curves, the simplest solution for retention of the scale grid would be to:

- a. Revise the "DRAW" routine to make the scale grid the first and second curves on the tape vice the second and third curves as in the existing routine, and





b. Make a simple modification to the analog display program to retain and display the first and second curves in the file plus display any number of following curves as desired.

Polaroid photography yields a picture of an 8 by 10 centimeter rectangle of the scope face at approximately 90 percent actual size. The hard copy enables the size of the graph relative to the titling to be greater than that needed for direct viewing due to greater ease in recognition of the title characters. The cost of the photographs is excessive, however, at approximately 30 cents per copy.

Complicated and densely packed curves are not acceptable for oscilloscope display due to the lack of curve labelling and the relatively low resolution coupled with the small size of the scope face.

### 3.2 Slow version with x-y plotter display element.

The slow version of the analog display program was originally assembled as a test instrument for determining the adequacy of the character display section of the fast version. By introducing delays at appropriate points in the program, the operation was slowed down sufficiently to drive an x-y plotter, providing a hard copy of all tested characters. Results on character readability were very good since the magnitude of the output steps was small enough and the timing slow enough for the plotter to follow without overshoot or round-off of the corners.

The success with the x-y plotter display of characters led to an attempt at a delayed curve point plotting routine. Results again were very good provided that the spacing between sequential curve points was not so large as to cause plotter overshoot. Any attempt to display coarse curve point data (eg. the scale grids) on the x-y plotter indicated the need for





interpolation between points, either before the data is placed in the memory file, or as the file is output to the conversion equipment.

A curve plotting routine incorporating linear interpolation between curve points was written using the algorithm of program LINE in reference [2]. The interpolation occurs as the point file is output to the D/A conversion equipment, but synthetic delays are still required in the computer to match the plotter characteristics.

A complete slow version of the analog display program was eventually assembled that would provide a hard copy of an entire graph on the x-y plotter. Pen control and curve definition was clear and accurate provided that the synthetic delays were adjusted to allow for plotter response. The size of the graphs could be adjusted up to maximum paper size, but with some change in the timing delays which are moderately sensitive to plotter scale changes. Preliminary tests have shown that the analog display program using the x-y plotter as the display element is just as fast (on a unit graph basis) as the existing digital equipment.

The revised sequencing of the slow version brings only one curve into the computer memory file at a time, so that approximately one-quarter of the memory is unused, and may be employed to add refinements to the display program as desired.

### 3.3 Summary.

A fast version of an analog display program has been assembled for the use with an oscilloscope as the display element. The display is clear and accurate, but is hampered by the small size of the scope face and by the flicker in the presentation. The flicker problem cannot be overcome using present equipment.



A slow version of the display program with an x-y plotter as the display element is slightly faster than the existing digital plotter on a unit graph basis. An interpolation routine has been implemented for point plotting so that coarse input data provides a continuous trace without plotter overshoot or corner round-off.



## BIBLIOGRAPHY

1. Control Data Corporation, Control Data 160 Computer Programming Manual.
2. Hogg, R. L., and Glover, D. C., Control System Programming, Remote Computing and Data Display. MS Thesis, USNPGS, 1963.



## APPENDIX I

### MAGNETIC TAPE DATA FORMAT

The magnetic tape generated by the "DRAW" routine and used for input to the analog display system program is constructed according to the format described below.

#### A. Titling data (multiple records).

##### 1. First record

- a. 12 bit binary mode.
- b. Length - four CDC 160 words.
- c. Word three contains an octal integer indicating the number of title lines. The remaining words are not used by the analog display program.

##### 2. Subsequent records.

- a. BCD characters in six bit binary mode.
- b. Length -  $120_d$  characters; the first character is not used by the analog display program.

#### B. Axes data (single record).

1. 12 bit binary mode.
2. Length -  $20_d$  CDC 160 words.
3. The second and eleventh words indicate the position of the graph origin in hundredths of an inch from the reference position. The remaining words are not used by the analog display program. The reference position is the starting point for all dimensions output by the "DRAW" routine.

#### C. Curve point data (multiple records).

1. 12 bit binary mode.





2. Length - 3677 (octal) CDC 160 words.

3. Horizontal and vertical ordinates alternate: both being measured in hundredths of an inch from the reference position.

4. The first four and the last three words are not used by the analog display program.

5. Two end flags of octal 3777 follow useful curve data.

D. End of file mark.

An end of file mark indicates the end of one complete set of graph plot data.

A complete description of the magnetic tape data format is available in Reference [2].



## APPENDIX II

### DIGITAL TO ANALOG EQUIPMENT CHARACTERISTICS

#### AND GRAPH POINT TRANSFORMATION SCHEME

A. The digital to analog (D/A) conversion equipment located in the computer laboratory has two channels for digital to analog conversion, each of which converts a twelve bit word output by the digital computer into a voltage in the range zero to minus ten volts. The corresponding bit patterns and output voltages are given in figure 4. The external function code for digital to analog conversion is 24XY octal, where Y indicates the desired channel and X controls operation of an "AND" gate that may be used directly or through a connected relay to blank the scope trace or lift the recorder pen. Each conversion takes approximately 20 microseconds (conversion equipment time only) and is accurate to approximately 10 millivolts.

B. A graph point transformation is required for a properly scaled and oriented display. The magnetic tape output of the "DRAW" routine contains curve data which is based on a reference point in the lower left hand corner of the plot. Curve points are given in hundredths of an inch from this reference point and are positive octal numbers since up and right are taken as the positive directions. Maximum acceptable dimensions for the graph plot generated by the "DRAW" routine are 10 inches in width by 15 inches in length.

The digital to analog conversion table (Figure 4), shows that as the octal input to the D/A conversion equipment increases, the voltage output by the equipment decreases. Normal display devices are oriented so that positive inputs yield positive indications to the right and up, so



that the curve data must be "inverted" for correct orientation.

In order to realize the full capabilities of the conversion equipment, the input data should be scaled to cover the entire range of possible output voltages. Thus, from consideration of the maximum magnitudes of input curve data and of the sizes of graph plots usually generated, a compromise scale expansion factor of three is indicated.

All that remains to complete the point transformation scheme is to add to the inverted and expanded data the value of the reference point in the new co-ordinate frame. This point was arbitrarily chosen at octal 2400, 2400 to leave adequate display area for graph titling.



## APPENDIX III

### MEMORY FORMAT OF GRAPH DATA FILE

The graph plot memory file contains a series of title line sections followed by curve point data.

The title line sections are arranged in packed BCD (i.e., two BCD characters per 160 word) with the end of a line indicated by the octal code 77. The next title line begins with the character following the end code. The number of lines in the entire title, and the file location of the beginning of the first line are set in low core cells.

The curve data file is bounded by file begin and file end locations set into two low core cells. Each pair of CDC 160 words contain the horizontal and vertical ordinates for digital to analog conversion and display.





## APPENDIX IV

### OPERATION OF THE ANALOG DISPLAY PROGRAM

#### A. Fast version

##### 1. Equipment required

CDC 160 digital computer  
CDC 163 magnetic tape unit  
Digital to analog conversion equipment  
Hewlett-Packard 122A oscilloscope  
Hewlett-Packard 650A oscillator  
General Radio 1217B pulse generator

2. Blanking scheme shown in Fig. 5.

3. Load the program in 0000-1773.

4. Run the program from the address selected from the table of starting addresses. (Fig. 3.)

#### B. Slow version

##### 1. Equipment required

CDC 160 digital computer  
CDC 163 magnetic tape unit  
Digital to analog conversion equipment  
Analog x-y plotter

2. Blanking scheme shown in Fig. 5. Set plotter switch for remote pen control.

3. Load program in 0000 2077.

4. For plotting, master clear and run. For tape control, run from the address selected from the table of starting addresses. (Fig. 3.)



## APPENDIX V

### PROGRAM ROUTINE LISTINGS

The routines are listed in the following order.

1. ZEST
2. ROT (fast)
3. ROT (slow)
4. READ
5. GREAD (fast)
6. GREAD (slow)
7. TAP
8. LTR (fast)
9. LTR (slow)
10. GRP (fast)
11. GRP (slow)
12. CHARACTER TABLE
13. RNC
14. LDA and DA (delays)
15. LOW CORE LIST



0100	0403	ZEST	REM		MAIN CONTROL ROUTINE
0101	6102	2S	LDN	03	ZERO START
0102	0401		NZF	UX	TWO START
0103	4024	UX	LDN	01	
0104	0101		STD	NOCUR	
0105	7040		SHA	01	
0106	0101	UU	JPI	READA	
0107	7046		SHA	01	
0110	7045		JPI	GREADA	
0111	6102	1ST	JPI	ROTA	
0112	0401		NZF	UZ	ONE START
0113	4024	UZ	LDN	01	
0114	2022		STD	NOCUR	
0115	4064		LDD	PA	
0116	6510		STD	FP	
0117	7522	4ST	NZB	UU	
0120	7523	STR1	EXF	BSOEF	FOUR START
0121	7600		EXF	STST	
0122	0202		INA		
0123	6503		LPN	02	
0124	7515	5ST	NZB	STR1	
0125	7516	STR2	EXF	BSOEF	FIVE START
0126	7600		EXF	STST	
0127	0202		INA		
0130	6503		LPN	02	
0131	7511	3ST	NZB	STR2	
0132	7113		EXF	RFOEF	THREE START
0133	7511	6ST	JFI	NSTOPI	
0134	7507	STR3	EXF	RWND	SIX START
0135	7600		EXF	STST	
0136	0240		INA		
0137	6403		LPN	40	
0140	7105		ZJB	STR3	
0141	1121	BSOEF	JFI	NSTOPI	
0142	1131	RFOEF		1121	
0143	1141	STST		1131	
0144	1161	RWND		1141	
0145	0007	NSTOP		1161	
	0024	NOCUR		07	
			EQU	24	

ZEST



0040	READA	EQU	40
0046	GREADA	EQU	46
0045	ROTA	EQU	45
0022	PA	EQU	22
0064	FP	EQU	64
0000		END	

ZEST





0100	0510	ROT	REM		DISPLAY LOOP
0101	4244		LCN	10	SET TITLE ITERATIONS
0102	2020	CIRCA	STF	S	
0103	4026		LDD	XPI	SET TITLE LINE
0104	2021		STD	XPA	INITIAL POINT
0105	0640		LDD	YPI	
0106	4027		ADN	40	
0107	2076		STD	YPA	
0110	4234		LDD	76	
0111	2025		STF	R	
0112	4203		LDD	IFTILI	
0113	0101	LTR	STF	AX	
0114	7041		SHA	01	DISPLAY A TITLE LINE
0115	0000	AX	JPI	LTRA	
0116	0601		ADN	01	
0117	4302		STB	AX	
0120	2226		LDF	OS	GET SET FOR NEXT LINE
0121	5027		RAD	YPA	
0122	5622		AOF	R	
0123	6510		NZB	LTR	
0124	5621		AOF	S	LOOP TO REPEAT TITLE
0125	6523		NZB	CIRCA	SET CURVE ITERATIONS
0126	0540		LCN	40	
0127	4216		STF	S	
0130	2075	CIRCB	LDD	75	
0131	4026		STD	XPA	
0132	2074		LDD	74	
0133	4027		STD	YPA	
0134	0101		SHA	01	DISPLAY ORIGIN
0135	7041		JPI	LTRA	
0136	0070			70	
0137	0101		SHA	01	DISPLAY CURVE DATA
0140	7042		JPI	GRPA	
0141	5604		AOF	S	LOOP TO REPEAT CURVE
0142	6512		NZB	CIRCB	LOOP TO REPEAT CYCLE
0143	6443		ZJB	ROT	
0144	0000	R			
0145	0000	S			
0146	0200	OS		200	

ROT (FAST)



0020	XPI	EQU	20
0021	YPI	EQU	21
0025	IFTIL	EQU	25
0026	XPA	EQU	26
0027	YPA	EQU	27
0041	LTRA	EQU	41
0042	GRPA	EQU	42
0000		END	

ROT (FAST)



			REM		ROTD DELAYED VERSION
			REM		DISPLAY LOOP
0100	2020	ROTD	LDD	XPI	
0101	4026		STD	XPA	SET TITLE LINE
0102	2021		LDD	YPI	INITIAL POINT
0103	0640		ADN	40	
0104	4027		STD	YPA	
0105	2076		LDD	76	
0106	4232		STF	R	
0107	2025		LDD	IFTIL	
0110	4203		STF	AX	
0111	0101	LTR	SHA	01	
0112	7041		JPI	LTRA	DISPLAY A TITLE LINE
0113	0000	AX			
0114	0601		ADN	01	
0115	4302		STB	AX	
0116	2223		LDF	OS	
0117	5027		RAD	YPA	GET SET FOR NEXT LINE
0120	5620		AOF	R	
0121	6510		NZB	LTR	
0122	2075		LDD	75	
0123	4026		STD	XPA	
0124	2074		LDD	74	
0125	4027		STD	YPA	
0126	0101		SHA	01	
0127	7041		JPI	LTRA	DISPLAY ORIGIN
0130	0070			70	
0131	0101	NXT	SHA	01	
0132	7042		JPI	GRPA	DISPLAY CURVE DATA
0133	2022		LDD	PA	
0134	4064		STD	FP	
0135	0101		SHA	01	
0136	7046		JPI	GREADA	
0137	6506		NZB	NXT	
0140	0000	R			
0141	0200	OS		200	
	0020	XPI	EQU	20	
	0021	YPI	EQU	21	
	0022	PA	EQU	22	
	0025	IFTIL	EQU	25	

ROT (SLOW)



0026	XPA	EQU	26
0027	YPA	EQU	27
0041	LTRA	EQU	41
0042	GRPA	EQU	42
0046	GREADA	EQU	46
0064	FP	EQU	64
0000		END	

ROT (SLOW)





		REM		READ4
		REM		READS AND TRANSFORMS
		REM		TITLE AND AXIS DATA
	1530	ORG	1530	
1530	0602	READ	ADN	02
1531	4275		STF	XX
1532	0101		SHA	01
1533	7043		JPI	TAPA
1534	6331			6331
1535	0074			74
1536	0100			100
1537	6137		NZF	TERA
1540	2477		LCD	77
1541	4077		STD	77
1542	4076		STD	76
1543	2025		LDD	IFTIL
1544	4205		STF	UA
1545	0701		SBN	01
1546	4022		STD	PA
1547	0400	TITL	LDN	
1550	4100		STI	
1551	0000	UA		
1552	5701		AOB	UA
1553	3606		SBF	G
1554	6505		NZB	TITL
1555	0101		SHA	01
1556	7043		JPI	TAPA
1557	5331			5331
1560	2600	F		2600
1561	3000	G		3000
1562	6120		NZF	TERB
1563	2302		LDB	G
1564	0701		SBN	01
1565	4202		STF	CO
1566	2100	J	LDI	
1567	0000	CO		
1570	6003		ZJF	R
1571	0720		SBN	20
1572	6140		NZF	K
1573	0501	R	LCN	01

SET RETURN ADDRESS

READ NUMBER OF  
TITLE LINES

SET FILE POINTERS

CLEAR TITLE SPACE

READ TITLE LINE

FIND LAST CHARACTER  
IN TITLE LINE

READ



1574	5305		RAB	CO	
1575	6507		NZB	J	
1576	4067	TERA	STD	TT	
1577	2200		LDF		
1600	1540			READ	10
1601	6104		NZF	TERR	
1602	4067	TERB	STD	TT	
1603	2200		LDF		
1604	1563			READ	33
1605	4206	TERR	STF	PEX	
1606	2067		LDD	TT	
1607	0204		LPN	04	
1610	6004		ZJF	NPAR	
1611	7704		HLT	04	PARITY STOP
1612	7101		JFI	01	
1613	0000	PEX			
1614	2067	NPAR	LDD	TT	
1615	0220		LPN	20	
1616	6003		ZJF	NEOF	
1617	7720		HLT	20	END OF FILE STOP
1620	7011		JPI	ZESTA	
1621	2067	NEOF	LDD	TT	
1622	7777		HLT	77	UNABLE TO PROCEED
1623	6501		NZB	01	
1624	6402		ZJB	02	
1625	7101	RET	JFI	01	EXIT
1626	0000	XX			
1627	2347	TITLA	LDB	F	
1630	4357		STB	UA	
1631	6562		NZB	TITL	
1632	5743	K	AOB	CO	
1633	4203		STF	CA	
1634	0477		LDN	77	
1635	4100		STI		ADD END CODE TO FILE
1636	0000	CA			
1637	5701		AOB	CA	
1640	2022		LDD	PA	
1641	4062		STD	P	
1642	2063		LDD	PH	GET SET TO PACK FILE
1643	6302		NJFI	H	

READ



1644	4463		SRD	PH	
1645	2365	H	LDB	F	
1646	0601		ADN	01	
1647	4202		STF	D	
1650	2100	E	LDI		
1651	0000	D			
1652	0277		LPN	77	
1653	4067		STD	TT	
1654	4463		SRD	PH	
1655	6214		PJF	AB	
1656	2067		LDD	TT	
1657	1562		LSI	P	
1660	6114		NZF	B	
1661	6013		ZJF	B	
1662	4067	TERC	STD	TT	
1663	2200		LDF		
1664	1712			READ	162
1665	6560		NZB	TERR	
1666	5422	RETA	AOD	PA	
1667	4064		STD	FP	SET FILE INDEX
1670	6543		NZB	RET	GO EXIT
1671	5462	AB	AOD	P	
1672	2067		LDD	TT	
1673	0111		SHA	11	
1674	4162	B	STI	P	PACK BCD FILE
1675	5724		AOB	D	
1676	3740		SBB	CA	
1677	6527		NZB	E	
1700	2062		LDD	P	
1701	4022		STD	PA	
1702	5477		AOD	77	CHECK FOR TITLES
1703	6554		NZB	TITLA	COMPLETED
1704	0101		SHA	01	
1705	7043		JPI	TAPA	READ AXIS DATA
1706	6331			6331	
1707	2600	U		2600	
1710	2640	V		2640	
1711	6527		NZB	TERC	
1712	0502		LCN	02	
1713	4226		STF	CU	

READ



1714	5215		RAF	X
1715	0502		LCN	02
1716	5211		RAF	PAP
1717	2310		LDB	U
1720	0601		ADN	01
1721	4202		STF	W
1722	2500	Z	LCI	
1723	0000	W		
1724	4067		STD	TT
1725	0102		SHA	02
1726	3067		ADD	TT
1727	3022	PAP	ADD	PA
1730	0640		ADN	40
1731	4076	X	STD	76
1732	5701		AOB	X
1733	5704		AOB	PAP
1734	5605		AOF	CU
1735	6447		ZJB	RETA
1736	0411		LDN	11
1737	5314		RAB	W
1740	6516		NZB	Z
1741	0000	CU		
	0022	PA	EQU	22
	0025	IFTIL	EQU	25
	0043	TAPA	EQU	43
	0062	P	EQU	62
	0063	PH	EQU	63
	0064	FP	EQU	64
	0067	TT	EQU	67
	0011	ZESTA	EQU	11
	0000		END	

TRANSFORM AXIS DATA

STORE ORIGIN LOCATION

READ





			REM		FAST GREAD
			REM		EXPAND BY 3
			REM		READS AND TRANSFORMS
			REM		CURVE DATA
0100	0602	GREAD	ADN	02	
0101	4251		STF	EXA	STORE RETURN ADDRESS
0102	2424		LCD	NOCUR	
0103	4261		STF	CU	STORE NO. CURVES
0104	2200		LDF		
0105	2600			2600	
0106	4206		STF	Y	SET FIRST WORD ADDRESS
0107	2064	FIG	LDD	FP	
0110	4066		STD	FB	SET FILE BEGIN INDEX
0111	0101		SHA	01	
0112	7043		JPI	TAPA	GET CURVE DATA
0113	6331			6331	FROM TAPE
0114	0000	Y			
0115	7701			7701	
0116	6150		NZF	TER	
0117	2303	OK	LDB	Y	
0120	0604		ADN	04	
0121	4065		STD	FPA	
0122	2200		LDF		
0123	3022			3022	
0124	4213		STF	BB	GET SET TO TRANSFORM
0125	0502	FIXA	LCN	02	CURVE DATA
0126	5211		RAF	BB	
0127	2565	FIX	LCI	FPA	
0130	3600		SBF		
0131	4000	END		4000	
0132	6021		ZJF	GAH	TEST FOR END OF DATA
0133	3302		ADB	END	
0134	4067		STD	TT	
0135	0102		SHA	02	TRANSFORM CURVE DATA
0136	3067		ADD	TT	
0137	3022	BB	ADD	PA	
0140	4164		STI	FP	
0141	5465		AOD	FPA	INDEX FILE POINTERS
0142	5464		AOD	FP	
0143	5704		AOB	BB	

GREAD (FAST)



0144	0202		LPN	02	
0145	6520		NZB	FIXA	
0146	6417		ZJB	FIX	
0147	2064	EXIT	LDD	FP	
0150	4023		STD	FE	
0151	7101		JFI	01	EXIT
0152	0000	EXA			
0153	2466	GAH	LCD	FB	END OF CURVE DATA
0154	3064		ADD	FP	
0155	5341		RAB	Y	
0156	6326		NJF	TESS	TEST FOR MEMORY
0157	3425		SBD	IFTIL	OVERFLOW
0160	6326		NJF	OFLO	
0161	5603	CURL	AOF	CU	
0162	6413		ZJB	EXIT	TEST FOR JOB COMPLETE
0163	6554		NZB	FIG	
0164	0000	CU			
0165	0000	ST			
0166	4301	TER	STB	ST	
0167	0204		LPN	04	
0170	6003		ZJF	CT	
0171	7704		HLT	04	PARITY STOP
0172	6553		NZB	OK	
0173	2306	CT	LDB	ST	
0174	0220		LPN	20	
0175	6003		ZJF	CK	
0176	7720		HLT	20	END OF FILE STOP
0177	7011		JPI	ZESTA	
0200	2313	CK	LDB	ST	
0201	7777		HLT	77	UNABLE TO PROCEED
0202	6501		NZB	01	
0203	6402		ZJB	02	
0204	0677	TESS	ADN	77	
0205	6724		NJB	CURL	
0206	0501	OFLO	LCN	01	MEMORY OVERFLOW
0207	5024		RAD	NOCUR	
0210	7016		JPI	5STA	
	0022	PA	EQU	22	
	0023	FE	EQU	23	
	0024	NOCUR	EQU	24	

GREAD (FAST)



0025:	IFTIL	EQU	25
0043:	TAPA	EQU	43
0064:	FP	EQU	64
0065:	FPA	EQU	65
0066:	FB	EQU	66
0011:	ZESTA	EQU	11
0016:	5STA	EQU	16
0067:	TT	EQU	67
0000:		END	

GREAD (FAST)



			REM		DELAYED VERSION
			REM		GREAD
			REM		READS CURVE POINTS
			REM		INTO COMPUTER MEMORY
			REM		USE WITH GRPXD ONLY
0100	0602	GREADX	ADN	02	
0101	4226		STF	EXA	STORE RETURN ADDRESS
0102	0101		SHA	01	
0103	7043		JPI	TAPA	GET CURVE POINTS
0104	6331			6331	
0105	2600	Y		2600	
0106	7701			7701	
0107	6122		NZF	TER	ERROR RETURN
0110	2303	OK	LDB	Y	
0111	0604		ADN	04	
0112	4065		STD	FPA	
0113	2165	FIX	LDI	FPA	
0114	3600		SBF		
0115	3777	END		3777	
0116	6006		ZJF	EXIT	
0117	3302		ADB	END	
0120	4164		STI	FP	STORE CURVE POINTS
0121	5465		AOD	FPA	IN FILE
0122	5464		AOD	FP	
0123	6510		NZB	FIX	
0124	2064	EXIT	LDD	FP	RETURN
0125	4023		STD	FE	
0126	7101		JFI	01	
0127	0000	EXA			
0130	0000	ST			
0131	4301	TER	STB	ST	
0132	0204		LPN	04	
0133	6003		ZJF	CT	
0134	7704		HLT	04	PARITY ERROR STOP
0135	6525		NZB	OK	
0136	2306	CT	LDB	ST	
0137	0220		LPN	20	
0140	6003		ZJF	CK	
0141	7720		HLT	20	END OF FILE STOP
0142	7013		JPI	2STA	RUN TO CONTINUE

GREAD. (SLOW)





0143	2313	CK	LDB	ST
0144	7777		HLT	77
0145	6501		NZB	01
0146	6402		ZJB	02
	0023	FE	EQU	23
	0043	TAPA	EQU	43
	0064	FP	EQU	64
	0065	FPA	EQU	65
	0013	2STA	EQU	13
	0000		END	

TAPE STATUS TO A  
UNABLE TO PROCEED  
START OVER FROM  
BEGINNING

GREAD (SLOW)



		REM		TAP - GENERAL
		REM		CDC 163 MAGNETIC
		REM		TAPE UNIT READ/WRITE
		REM		ROUTINE
0100	0602	TAP1	ADN 02	
0101	4200		STF	STORE RETURN ADDRESS
0102	0000	RADD		
0103	2301		LDB RADD	BUILD EXTERNAL
0104	4202		STF 02	FUNCTION CODE
0105	2100	LDARG	LDI	
0106	0000		BSS 01	
0107	4244		STF TAPTRM 01	
0110	1200		LPF	
0111	3177		3177	
0112	4273		STF RDFWD 01	
0113	0207		LPN 07	
0114	3200		ADF	BUILD STATUS REQ.
0115	1140		1140	
0116	4261		STF STATCD	
0117	7560	STREQ	EXF STATCD	STATUS REQUEST
0120	7600		INA	
0121	0202		LPN 02	
0122	6503		NZB STREQ	LOOP UNTIL READY
0123	2230		LDF TAPTRM 01	BUILD CODE FOR
0124	1200		LPF	INPUT OR OUTPUT
0125	0600		600	
0126	6052		ZJF MTERR	
0127	0111		SHA 11	
0130	0110		SHA 10	
0131	0103		SHA 03	
0132	3200		ADF	
0133	7115		7115	
0134	4224		STF MTINP	STORE IT
0135	7500		EXF	SELECT ODD PARITY
0136	1171		1171	
0137	2214		LDF TAPTRM 01	CHECK DESIRED PARITY
0140	6303		NJF 03	
0141	7500		EXF	EVEN PARITY DESIRED
0142	1172		1172	SELECT EVEN PARITY
0143	5735		AOB LDARG 01	

TAP



0144	4202		STF	GETINT	01	
0145	2100	GETINT	LDI			GET INITIAL ADDRESS
0146	0000		BSS	01		
0147	4226		STF	MTEXT	01	
0150	5702		AOB	GETINT	01	
0151	4202		STF	TAPTRM	01	
0152	2100	TAPTRM	LDI			GET TERMINAL ADDR.
0153	0000		BSS	01		
0154	4205		STF	MTINP	01	
0155	0503		LCN	03		
0156	4310		STB	GETINT	01	
0157	7526	RDWT	EXF	RDFWD	01	
0160	7215	MTINP	INP	MTEXT	01	INPUT/OUTPUT BLOCK
0161	0000		BSS	01		
0162	7515		EXF	STATCD		STATUS REQUEST
0163	7600		INA			
0164	0274		LPN	74		
0165	4211		STF	BANKSW		STORE STATUS RESP.
0166	6125		NZF	TRYAGN		ERROR JUMP
0167	0401		LDN	01		
0170	0601	ERRET	ADN	01		BUILD, SET EXIT
0171	3316		ADB	TAPTRM	01	ADDRESS
0172	4203		STF	MTEXT	01	
0173	2203		LDF	BANKSW		
0174	7101	MTEXT	JFI	01		
0175	0000		BSS	01		
0176	0000	BANKSW				
0177	0000	STATCD				
0200	0602	MTERR	ADN	02		DELAY LOOP
0201	6501		NZB	01		
0202	5774		AOB	LDARG	01	BUILD ERROR EXIT
0203	4306		STB	MTEXT	01	
0204	7500	RDFWD	EXF			READ FORWARD OVER
0205	0000		BSS	01		END OF FILE
0206	2333		LDB	TAPTRM	01	
0207	6202		PJF	GOJUMP		
0210	7600		INA			
0211	6515	GOJUMP	NZB	MTEXT		UNCONDITIONAL ERROR
0212	6416		ZJB	MTEXT		JUMP TO EXIT
0213	5745	TRYAGN	AOB	GETINT	01	TRY 3 TIMES

TAP



0214	6424	ZJB	ERRET		THEN ERROR EXIT
0215	2310	LDB	RDFWD	01	
0216	0207	LPN	07		
0217	3200	ADF			
0220	1120		1120		
0221	4212	STF	TAPBKS	01	
0222	0620	ADN	20		
0223	4212	STF	TAPBKS	03	
0224	7511	EXF	TAPBKS	03	
0225	7600	INA			
0226	0202	LPN	02		
0227	6503	NZB	03		LOOP UNTIL READY
0230	0602	ADN	02		
0231	6501	NZB	01		DELAY LOOP
0232	7500	TAPBKS: EXF			BACKSPACE TO
0233	0000	BSS	01		END OF FILE
0234	7500	EXF			
0235	0000	BSS	01		
0236	7600	INA			
0237	0202	LPN	02		
0240	6504	NZB	04		LOOP UNTIL READY
0241	6462	ZJB	RDWT		GO TRY AGAIN
	0000	END			

TAP





			REM	
			REM	
			REM	
			REM	
			REM	
			REM	
			REM	
0100	0602	LTR3B	ADN	02
0101	4210		STF	PP
0102	2026	SM	LDD	XPA
0103	4060		STD	XP
0104	2027		LDD	YPA
0105	4061		STD	YP
0106	2304		LDB	SM
0107	4214		STF	PO
0110	2100		LDI	
0111	0000	PP		
0112	0701		SBN	01
0113	4232		STF	FWA
0114	5703		AOB	PP
0115	4237		STF	EXADD
0116	2245		LDF	PUP
0117	4207		STF	CDA
0120	2236		LDF	KH
0121	6302		NJF	PO
0122	4634		SRF	KH
0123	2026	PO	LDD	XPA
0124	4077		STD	OB
0125	7500	CD	EXF	
0126	0000	CDA		
0127	7326		OUT	KK
0130	0100			100
0131	5703		AOB	CDA
0132	5707		AOB	PO
0133	0207		LPN	07
0134	6511		NZB	PO
0135	4621	H	SRF	KH
0136	6203		PJF	O
0137	2220		LDF	NOP
0140	6103		NZF	S

OUTPUTS A LINE OF BCD  
CHARACTERS TO D/A  
ARGUMENT IS FIRST WORD  
ADDR. OF PACKED FILE  
CHARACTER TABLE  
MUST BE LOCATED IN  
CELLS 1000-1527

STORE ARGUMENT ADDR.

SET GRID POINTERS

SET CHARAC. INDEX

SET RETURN ADDRESS

OUTPUT INITIAL POINT

LTR (FAST)



0141	5604	O	AOF	FWA	
0142	2216		LDF	SH	
0143	4203	S	STF	SHIFT	
0144	2100		LDI		
0145	0000	FWA			
0146	0000	SHIFT			
0147	0277		LPN	77	GET BCD FROM FILE
0150	0777		SBN	77	CHECK FOR END
0151	6114		NZF	CONT	JUMP TO CARRY ON
0152	2305	EXIT	LDB	FWA	
0153	7101		JFI	01	EXIT WITH FILE INDEX
0154	0000	EXADD			IN ARITHMETIC REGISTER
0155	0077	KK		77	
0156	5252	KH		5252	
0157	0600	NOP		600	
0160	0111	SH		111	
0161	1077	TAD		1077	
0162	2411	PDN		2411	
0163	2401	PUP		2401	
0164	5060	RADI		5060	
0165	3304	CONT	ADB	TAD	SET TABLE ADDRESS
0166	4202		STF	TENT	
0167	2100		LDI		
0170	0000	TENT			
0171	4062		STD	CP	SET MOVEMENT TABLE
0172	2063		LDD	CH	ADDRESS
0173	6302		NJF	Q	
0174	4463		SRD	CH	
0175	2312	Q	LDB	PUP	
0176	4256		STF	C	SET EXF CODE
0177	2313	STO	LDB	RADI	
0200	4251		STF	B	
0201	0101	R	SHA	01	
0202	7044		JPI	RNCA	
0203	6056		ZJF	SKI	
0204	4241		STF	MOV	STORE MOTION CODE
0205	0775		SBN	75	AND DECODE FOR STEP
0206	6025		ZJF	DOWN	SIZE, NUMBER OF
0207	0701		SBN	01	STEPS, DIRECTION
0210	6025		ZJF	UP	AND PEN CONTROL

LTR (FAST)



0211	0701		SBN	01	
0212	6455		ZJB	H	
0213	0677		ADN	77	
0214	0217		LPN	17	
0215	4231		STF	NUM	
0216	2630		LCF	NUM	
0217	4227		STF	NUM	
0220	2225		LDF	MOV	
0221	0220		LPN	20	
0222	6102		NZF	Z	
0223	0410		LDN	10	
0224	4223	Z	STF	SIZE	
0225	2220		LDF	MOV	
0226	0111		SHA	11	
0227	6321		NJF	A	GO EXECUTE
0230	2617	NEG	LCF	SIZE	
0231	4216		STF	SIZE	
0232	6316		NJF	A	GO EXECUTE
0233	2351	DOWN	LDB	PDN	SET FOR PEN DOWN
0234	6102		NZF	SCC	
0235	2352	UP	LDB	PUP	SET FOR PEN UP
0236	4216	SCC	STF	C	
0237	2060		LDD	XP	
0240	4077		STD	OB	
0241	7513		EXF	C	
0242	7331		OUT	OBA	EXECUTE PEN CONTROL
0243	0100			100	
0244	6545		NZB	STO	
0245	0000	MOV			
0246	0000	NUM			
0247	0000	SIZE			
0250	2301	A	LDB	SIZE	
0251	5060	B	RAD	XP	
0252	4077		STD	OB	
0253	7500		EXF		
0254	0000	C			
0255	7316		OUT	OBA	OUTPUT A STEP
0256	0100			100	
0257	5711		AOB	NUM	
0260	6510		NZB	A	

LTR (FAST)



0261	5710	SK	AOB	B	
0262	5706		AOB	C	RESET FOR VERTICAL
0263	0207		LPN	07	MOTION
0264	0703		SBN	03	
0265	6564		NZB	R	
0266	0502		LCN	02	RESET FOR HORIZ.
0267	5316		RAB	B	MOTION
0270	0502		LCN	02	
0271	5315		RAB	C	
0272	6571		NZB	R	
0273	0077	OBA		77	
	0077	OB	EQU	77	
	0026	XPA	EQU	26	
	0027	YPA	EQU	27	
	0044	RNCA	EQU	44	
	0060	XP	EQU	60	
	0061	YP	EQU	61	
	0062	CP	EQU	62	
	0063	CH	EQU	63	
	0000		END		

LTR (FAST)





			REM		DELAYED VERSION
			REM		OUTPUTS A LINE OF BCD
			REM		CHARACTERS TO D/A
			REM		ARGUMENT IS FIRST WORD
			REM		ADDR. OF PACKED FILE
			REM		CHARACTER TABLE
			REM		MUST BE LOCATED IN
			REM		CELLS 1000-1527
0100	0602	LTR3D	ADN	02	
0101	4210		STF	PP	STORE ARGUMENT ADDR.
0102	2026	SM	LDD	XPA	
0103	4060		STD	XP	
0104	2027		LDD	YPA	SET GRID POINTERS
0105	4061		STD	YP	
0106	2304		LDB	SM	
0107	4214		STF	PO	
0110	2100		LDI		
0111	0000	PP			
0112	0701		SBN	01	
0113	4235		STF	FWA	SET CHARAC. INDEX
0114	5703		AOB	PP	
0115	4242		STF	EXADD	SET RETURN ADDRESS
0116	2250		LDF	PUP	
0117	4207		STF	CDA	
0120	2241		LDF	KH	
0121	6302		NJF	PO	
0122	4637		SRF	KH	
0123	2026	PO	LDD	XPA	
0124	4077		STD	OB	
0125	7500	CD	EXF		
0126	0000	CDA			
0127	7331		OUT	KK	OUTPUT INITIAL POINT
0130	0100			100	
0131	5703		AOB	CDA	
0132	5707		AOB	PO	
0133	0207		LPN	07	
0134	6511		NZB	PO	
0135	0101		SHA	01	
0136	7050		JPI	LDA	DELAY
0137	0300			300	

LTR (SLOW)



0140	4621	H	SRF	KH	
0141	6203		PJF	O	
0142	2220		LDF	NOP	
0143	6103		NZF	S	
0144	5604	O	AOF	FWA	
0145	2216		LDF	SH	
0146	4203	S	STF	SHIFT	
0147	2100		LDI		
0150	0000	FWA			
0151	0000	SHIFT			
0152	0277		LPN	77	GET BCD FROM FILE
0153	0777		SBN	77	CHECK FOR END
0154	6114		NZF	CONT	JUMP TO CARRY ON
0155	2305	EXIT	LDB	FWA	
0156	7101		JFI	01	EXIT WITH FILE INDEX
0157	0000	EXADD			IN ARITHMETIC REGISTER
0160	0077	KK		77	
0161	5252	KH		5252	
0162	0600	NOP		600	
0163	0111	SH		111	
0164	1077	TAD		1077	
0165	2411	PDN		2411	
0166	2401	PUP		2401	
0167	5060	RADI		5060	
0170	3304	CONT	ADB	TAD	SET TABLE ADDRESS
0171	4202		STF	TENT	
0172	2100		LDI		
0173	0000	TENT			
0174	4062		STD	CP	SET MOVEMENT TABLE
0175	2063		LDD	CH	ADDRESS
0176	6302		NJF	Q	
0177	4463		SRD	CH	
0200	2312	Q	LDB	PUP	
0201	4261		STF	C	SET EXF CODE
0202	2313	STO	LDB	RADI	
0203	4254		STF	B	
0204	0101	R	SHA	01	
0205	7044		JPI	RNCA	
0206	6064		ZJF	SK	
0207	4244		STF	MOV	STORE MOTION CODE

LTR (SLOW)



0210	0775		SBN	75		
0211	6025		ZJF	DOWN		
0212	0701		SBN	01		
0213	6025		ZJF	UP		
0214	0701		SBN	01		
0215	6455		ZJB	H		
0216	0677		ADN	77		
0217	0217		LPN	17		
0220	4234		STF	NUM		
0221	2633		LCF	NUM		
0222	4232		STF	NUM		
0223	2230		LDF	MOV		
0224	0220		LPN	20		
0225	6102		NZF	Z		
0226	0410		LDN	10		
0227	4226	Z	STF	SIZE		
0230	2223		LDF	MOV		
0231	0111		SHA	11		
0232	6324		NJF	A		GO EXECUTE
0233	2622	NEG	LCF	SIZE		
0234	4221		STF	SIZE		
0235	6321		NJF	A		GO EXECUTE
0236	2351	DOWN	LDB	PDN		SET FOR PEN DOWN
0237	6102		NZF	SCC		
0240	2352	UP	LDB	PUP		SET FOR PEN UP
0241	4221	SCC	STF	C		
0242	2060		LDD	XP		
0243	4077		STD	OB		
0244	7516		EXF	C		
0245	7337		OUT	OBA		EXECUTE PEN CONTROL
0246	0100			100		
0247	0101		SHA	01		
0250	7050		JPI	LDA		DELAY
0251	0007			07		
0252	6450		ZJB	STO		
0253	0000	MOV				
0254	0000	NUM				
0255	0000	SIZE				
0256	2301	A	LDB	SIZE		
0257	5060	B	RAD	XP		

LTR (SLOW)



0260	4077		STD	OB	
0261	7500		EXF		
0262	0000	C			
0263	7321		OUT	OBA	OUTPUT A STEP
0264	0100			100	
0265	0101		SHA	01	
0266	7050		JPI	LDA	DELAY
0267	0007			07	
0270	5714		AOB	NUM	
0271	6513		NZB	A	
0272	5713	SK	AOB	B	
0273	5711		AOB	C	RESET FOR VERTICAL
0274	0207		LPN	07	MOTION
0275	0703		SBN	03	
0276	6572		NZB	R	
0277	0502		LCN	02	RESET FOR HORIZ.
0300	5321		RAB	B	MOTION
0301	0502		LCN	02	
0302	5320		RAB	C	
0303	6577		NZB	R	
0304	0077	OBA		77	
	0077	OB	EQU	77	
	0026	XPA	EQU	26	
	0027	YPA	EQU	27	
	0044	RNCA	EQU	44	
	0047	DA	EQU	47	
	0050	LDA	EQU	50	
	0060	XP	EQU	60	
	0061	YP	EQU	61	
	0062	CP	EQU	62	
	0063	CH	EQU	63	
	0000		END		

LTR (SLOW)





			REM	
			REM	
			REM	
			REM	
0100	0602	RNC	ADN	02
0101	4213		STF	A
0102	4463		SRD	CH
0103	6204		PJF	B
0104	2162		LDI	CP
0105	6105		NZF	C
0106	6004		ZJF	C
0107	5462	B	AOD	CP
0110	2162		LDI	CP
0111	0111		SHA	11
0112	0277	C	LPN	77
0113	7101		JFI	01
0114	0000	A		
	0062	CP	EQU	62
	0063	CH	EQU	63
	0000		END	

READ NEXT WORD FROM  
 FILE OF TWO WORDS PER  
 160 WORD.  
 EG PACKED BCD

RNC



0100	0602		REM		LONG DELAY
0101	4202		ADN	02	
0102	2100		STF	A	
0103	0000	A	LDI		
0104	4067		STD	TT	
0105	2467		LCD	TT	
0106	4067		STD	TT	
0107	5704		AOB	A	
0110	4206		STF	EXH	
0111	0101	INN	SHA	01	
0112	7047		JPI	DA	
0113	5467		AOD	TT	
0114	6503		NZB	INN	
0115	7101		JFI	01	
0116	0000	EXH			
	0067	TT	EQU	67	
	0047	DA	EQU	47	
	0000		END		

0100	0602	SHORT	REM		SHORT DELAY
0101	4205		ADN	02	
0102	2605		STF	EXH	
0103	0601		LCF	DE	
0104	6501		ADN	01	
0105	7101		NZB	01	
0106	0000	EXH	JFI	01	
0107	1000	DE		1000	
	0000		END		

# DELAY ROUTINES



			REM		OUTPUTS POINT FILE
			REM		TO D/A ONE TIME ONLY
			REM		X POINT PEN UP
			REM		Y POINT PEN DOWN
0100	0602	GRP3B	ADN	02	
0101	4226		STF	G	STORE RETURN ADDRESS
0102	2022		LDD	FI	
0103	4064		STD	FP	INITIALIZE FILE POINTER
0104	2224	M	LDF	B	
0105	4204		STF	C	INITIALIZE EXF CODE
0106	2164	J	LDI	FP	
0107	4077		STD	OB	SET OUTPUT BUFFER
0110	7500		EXF		
0111	0000	C			
0112	7317		OUT	K	OUTPUT D/A
0113	0100			100	
0114	5464		AOD	FP	INDEX FILE POINTER
0115	3423		SBD	FE	CHECK FOR GRAPH END
0116	6010		ZJF	N	GO EXIT IF END
0117	2306		LDB	C	
0120	0611		ADN	11	
0121	4310		STB	C	RESET EXF CODE
0122	0207		LPN	07	
0123	0703		SBN	03	
0124	6516		NZB	J	CYCLE BACK FOR Y MOVE
0125	6421		ZJB	M	CYCLE BACK FOR X MOVE
0126	7101	N	JFI	01	EXIT
0127	0000	G			EXIT ADDRESS
0130	2401	B		2401	EXF CODE
0131	0077	K		77	OUTPUT BUFFER
	0077	OB	EQU	77	
	0022	FI	EQU	22	
	0023	FE	EQU	23	
	0064	FP	EQU	64	
	0000		END		

GRP (FAST)



		REM		DELAYED VERSION
		REM		POINT DISPLAY WITH
		REM		LINEAR INTERPOLATION
0100	0602	GRPXD	ADN 02	
0101	4254		STF EXH	STORE RETURN ADDR.
0102	2022		LDD FI	
0103	4064		STD FP	INITIALIZE FILE
0104	2164		LDI FP	POINTER
0105	4072		STD A	
0106	2472		LCD A	
0107	4060		STD XP	
0110	0102		SHA 02	
0111	3020		ADD XI	
0112	5060		RAD XP	
0113	7500		EXF	OUTPUT INITIAL
0114	2401		2401	X-ORDINATE
0115	7341		OUT XA	
0116	0061		XP	01
0117	5464		AOD FP	
0120	2164		LDI FP	
0121	4073		STD B	
0122	2473		LCD B	
0123	4061		STD YP	
0124	0102		SHA 02	
0125	3021		ADD YI	
0126	5061		RAD YP	
0127	7517		EXF YUC	OUTPUT INITIAL
0130	7327		OUT YA	Y-ORDINATE
0131	0062		YP	01
0132	0101		UHA 01	
0133	7050		JPI LDA	DELAY
0134	0300		300	
0135	7500		EXF	LOWER PEN
0136	2411		2411	
0137	7317		OUT XA	
0140	0061		XP	01
0141	0101		SHA 01	
0142	7050		JPI LDA	DELAY
0143	0010		10	
0144	6021		ZJF BETA	CONTINUE

GRP (SLOW)





0145	7500	EXIT	EXF		RAISE PEN PRIOR
0146	2402	YUC		2402	TO EXIT
0147	7310		OUT	YA	
0150	0062			YP	01
0151	0101		SHA	01	
0152	7050		JPI	LDA	DELAY
0153	0010			10	
0154	7101		JFI	01	RETURN
0155	0000	EXH			
0156	0060	XA		XP	
0157	0061	YA		YP	
0160	2164	ALFA	LDI	FP	
0161	4072		STD	A	
0162	5464		AOD	FP	
0163	2164		LD	FP	
0164	4073		STD	B	
0165	5464	BETA	AOD	FP	
0166	3423		SBD	FE	TEST FOR END
0167	6422		ZJB	EXIT	
0170	2164		LDI	FP	
0171	3472		SBD	A	
0172	4072		STD	A	DELTA X
0173	6303		NJF	ANEG	
0174	0401		LDN	01	SET CODE FOR +X
0175	6104		NZF	STIC	MOTION
0176	2472	ANEG	LCD	A	
0177	4072		STD	A	
0200	0402		LDN	02	SET CODE FOR -X
0201	4230	STIC	STF	ICODE	MOTION
0202	5464		AOD	FP	
0203	2164		LDI	FP	
0204	3473		SBD	B	
0205	4073		STD	B	DELTA B
0206	6303		NJF	BNEG	
0207	0404		LDN	04	SET CODE FOR +Y
0210	6104		NZF	STJC	MOTION
0211	2473	BNEG	LCD	B	
0212	4073		STD	B	
0213	0410		LDN	10	SET CODE FOR -Y
0214	4216	STJC	STF	JCODE	MOTION

GRP (SLOW)



0215	3214		ADF	ICODE	
0216	4215		STF	IBOTH	
0217	2072		LDD	A	
0220	3473		SBD	B	
0221	6221		PJF	AMBP	
0222	2073	AMBN	LDD	B	DELTA Y IS LONGEST
0223	4212		STF	NLONG	
0224	2072		LDD	A	
0225	4211		STF	NSHORT	
0226	2204		LDF	JCODE	
0227	4205		STF	MOSTLY	
0230	6122		NZF	CONT	
0231	0000	ICODE			
0232	0000	JCODE			
0233	0000	IBOTH			
0234	0000	MOSTLY			
0235	0000	NLONG			
0236	0000	NSHORT			
0237	0000	NSWITC			
0240	0000	MOVE			
0241	6561	ALFA1	NZB	ALFA	
0242	0003	SIZE		03	
0243	0000	LIMIT			
0244	2072	AMBP	LDD	A	DELTA X IS LONGEST
0245	4310		STB	NLONG	
0246	2073		LDD	B	
0247	4311		STB	NSHORT	
0250	2317		LDB	ICODE	
0251	4315		STB	MOSTLY	
0252	2314	CONT	LDB	NSHORT	SET UP BEST PATH
0253	4314		STB	NSWITC	PARAMETERS
0254	2717		LCB	NLONG	
0255	4312		STB	LIMIT	
0256	2072		LDD	A	
0257	6103		NZF	TEST	SKIP OUTPUT IF
0260	2073		LDD	B	DELTA-X AND DELTA-Y
0261	6054		ZJF	SKP	BOTH ZERO
0262	2325	TEST	LDB	NLONG	TEST FOR MOTION
0263	3724		SBB	NSWITC	
0264	3725		SBB	NSWITC	

GRP (SLOW)



0265	6305		NJF	ZAG	
0266	2330	ZIG	LDB	NSHORT	RESET FOR NEXT TEST
0267	5330		RAB	NSWITC	
0270	2334		LDB	MOSTLY	
0271	6105		NZF	G	
0272	2334	ZAG	LDB	NSHORT	RESET FOR NEXT TEST
0273	3736		SBB	NLONG	
0274	5335		RAB	NSWITC	
0275	2342		LDB	IBOTH	
0276	4336	G	STB	MOVE	
0277	0203		LPN	03	DECODE X MOTION
0300	6007		ZJF	XOUT	
0301	0201		LPN	01	
0302	6103		NZF	XRT	
0303	2341	XLFT	LDB	SIZE	
0304	6102		NZF	QA	
0305	2743	XRT	LCB	SIZE	
0306	5060	QA	RAD	XP	
0307	7500	XOUT	EXF		OUTPUT X MOTION
0310	2411			2411	
0311	7327		OUT	X	
0312	0061			XP	01
0313	2353		LDB	MOVE	
0314	0214		LPN	14	DECODE Y MOTION
0315	6007		ZJF	YOUT	
0316	0204		LPN	04	
0317	6103		NZF	YUP	
0320	2356	YDN	LDB	SIZE	
0321	6102		NZF	QB	
0322	2760	YUP	LCB	SIZE	
0323	5061	QB	RAD	YP	
0324	7500	YOUT	EXF		OUTPUT Y MOTION
0325	2412			2412	
0326	7313		OUT	Y	
0327	0062			YP	01
0330	0101		SHA	01	
0331	7050		JPI	LDA	DELAY
0332	0001			01	
0333	5770		AOB	LIMIT	TEST TO CONTINUE
0334	6552		NZB	TEST	INTERPOLATION LOOP

GRP (SLOW)



0335	0501	SKP	LCN	01
0336	5064		RAD	FP
0337	6576		NZB	ALFA1
0340	0060	X		XP
0341	0061	Y		YP
	0020	XI	EQU	20
	0021	YI	EQU	21
	0022	FI	EQU	22
	0023	FE	EQU	23
	0047	DA	EQU	47
	0050	LDA	EQU	50
	0060	XP	EQU	60
	0061	YP	EQU	61
	0064	FP	EQU	64
	0072	A	EQU	72
	0073	B	EQU	73
	0000		END	

GO TO NEXT POINT

GRP (SLOW)





	1000	ORG	1000	
1000	1077		1077	SPACE
1001	1100		1100	ONE
1002	1105		1105	TWO
1003	1113		1113	THREE
1004	1121		1121	FOUR
1005	1130		1130	FIVE
1006	1135		1135	SIX
1007	1143		1143	SEVEN
1010	1150		1150	EIGHT
1011	1156		1156	NINE
1012	1163		1163	ZERO
1013	1171		1171	EQUAL
1014	1176		1176	NOT EQUAL
1015	1077		1077	SPACE
1016	1077		1077	SPACE
1017	1077		1077	SPACE
1020	1077		1077	SPACE
1021	1205		1205	SLASH
1022	1215		1215	S
1023	1225		1225	T
1024	1233		1233	U
1025	1241		1241	V
1026	1253		1253	W
1027	1263		1263	X
1030	1273		1273	Y
1031	1302		1302	Z
1032	1077		1077	SPACE
1033	1312		1312	COMMA
1034	1316		1316	OPEN
1035	1077		1077	SPACE
1036	1077		1077	SPACE
1037	1077		1077	SPACE
1040	1323		1323	MINUS
1041	1327		1327	J.
1042	1333		1333	KI
1043	1344		1344	LI
1044	1351		1351	MI
1045	1357		1357	NI
1046	1363		1363	OI

CHARACTER TABLE:



1047	1367	1367	P
1050	1374	1374	Q
1051	1403	1403	R
1052	1323	1323	MINUS
1053	1411	1411	DOLLAR SIGN
1054	1374	1374	STAR
1055	1077	1077	SPACE
1056	1077	1077	SPACE
1057	1077	1077	SPACE
1060	1421	1421	PLUS
1061	1427	1427	A
1062	1435	1435	B
1063	1444	1444	C
1064	1451	1451	D
1065	1457	1457	E
1066	1466	1466	F
1067	1474	1474	G
1070	1502	1502	H
1071	1510	1510	I
1072	1077	1077	SPACE
1073	1516	1516	PERIOD
1074	1522	1522	CLOSE
1075	1077	1077	SPACE
1076	1077	1077	SPACE
1077	1077	1077	SPACE
1100	2477	2477	SPACE
1101	7506	7506	ONE
1102	0043	43	
1103	1076	1076	
1104	2464	2464	
1105	7700	7700	
1106	2375	2375	TWO
1107	4604	4604	
1110	0604	604	
1111	4676	4676	
1112	2564	2564	
1113	7700	7700	
1114	7506	7506	THREE
1115	0444	444	
1116	0004	04	

# CHARACTER TABLE



1117	0446	446	
1120	7625	7625	
1121	6477	6477	
1122	2375	2375	FOUR
1123	0010	10	
1124	7663	7663	
1125	7500	7500	
1126	4410	4410	
1127	7622	7622	
1130	6277	6277	
1131	7506	7506	FIVE
1132	0446	446	
1133	0406	406	
1134	7622	7622	
1135	6477	6477	
1136	0024	24	SIX
1137	7500	7500	
1140	5006	5006	
1141	0446	446	
1142	7625	7625	
1143	6277	6277	
1144	2375	2375	SEVEN
1145	0010	10	
1146	4676	4676	
1147	2564	2564	
1150	7700	7700	
1151	7506	7506	EIGHT
1152	0446	446	
1153	0406	406	
1154	4446	4446	
1155	4476	4476	
1156	2577	2577	
1157	7506	7506	NINE
1160	1046	1046	
1161	4406	4406	
1162	7622	7622	
1163	6277	6277	
1164	7510	7510	ZERO
1165	1050	1050	
1166	5004	5004	

CHARACTER TABLE



1167	1076	1076	
1170	2464	2464	
1171	7700	7700	
1172	0021	21	EQUAL
1173	7506	7506	
1174	2146	2146	
1175	7626	7626	
1176	6277	6277	
1177	0021	21	NOT EQUAL
1200	7506	7506	
1201	2146	2146	
1202	0003	03	
1203	2100	2100	
1204	4676	4676	
1205	2477	2477	
1206	0061	61	SLASH
1207	7500	7500	
1210	0302	302	
1211	0302	302	
1212	0302	302	
1213	0376	376	
1214	2265	2265	
1215	7700	7700	
1216	0001	01	S
1217	7500	7500	
1220	4106	4106	
1221	0446	446	
1222	0406	406	
1223	4176	4176	
1224	2247	2247	
1225	7700	7700	
1226	2275	2275	T
1227	0010	10	
1230	6200	6200	
1231	1076	1076	
1232	2264	2264	
1233	7700	7700	
1234	0024	24	U
1235	7500	7500	
1236	5006	5006	

CHARACTER TABLE





1237	1076	1076
1240	2264	2264
1241	7700	7700
1242	0010	10
1243	7500	7500
1244	4202	4202
1245	4202	4202
1246	4402	4402
1247	0402	402
1250	0202	202
1251	0276	276
1252	2264	2264
1253	7700	7700
1254	0024	24
1255	7500	7500
1256	5003	5003
1257	2400	2400
1260	5003	5003
1261	1076	1076
1262	2264	2264
1263	7700	7700
1264	7500	7500
1265	0403	403
1266	2200	2200
1267	5000	5000
1270	2203	2203
1271	0476	476
1272	2264	2264
1273	7700	7700
1274	7506	7506
1275	1076	1076
1276	6375	6375
1277	0044	44
1300	0676	676
1301	2262	2262
1302	7700	7700
1303	2375	2375
1304	4602	4602
1305	0202	202
1306	0202	202

V

W

X

Y

Z

CHARACTER TABLE



1307	0202	202	
1310	4676	4676	
1311	2564	2564	
1312	7700	7700	
1313	7502	7502	COMMA
1314	4276	4276	
1315	2221	2221	
1316	7700	7700	
1317	0242	242	OPEN
1320	7542	7542	
1321	1402	1402	
1322	7622	7622	
1323	6577	6577	
1324	0022	22	MINUS
1325	7504	7504	
1326	7622	7622	
1327	6277	6277	
1330	7506	7506	J.
1331	1076	1076	
1332	2264	2264	
1333	7700	7700	
1334	7500	7500	KI
1335	1076	1076	
1336	2275	2275	
1337	0042	42	
1340	4242	4242	
1341	0242	242	
1342	0242	242	
1343	7622	7622	
1344	7700	7700	
1345	0024	24	LI
1346	7500	7500	
1347	5006	5006	
1350	7622	7622	
1351	7700	7700	
1352	7500	7500	MI
1353	1003	1003	
1354	5000	5000	
1355	2403	2403	
1356	5076	5076	

# CHARACTER TABLE



1357	2277	2277	
1360	7500	7500	N
1361	1006	1006	
1362	5076	5076	
1363	2277	2277	
1364	7506	7506	O
1365	1046	1046	
1366	5076	5076	
1367	2577	2577	
1370	7500	7500	P
1371	1006	1006	
1372	4446	4446	
1373	7625	7625	
1374	6277	6277	
1375	7510	7510	Q OR STAR
1376	1050	1050	
1377	5004	5004	
1400	1062	1062	
1401	6210	6210	
1402	7622	7622	
1403	6277	6277	
1404	7500	7500	R
1405	1006	1006	
1406	4446	4446	
1407	0022	22	
1410	4476	4476	
1411	2377	2377	
1412	7510	7510	DOLLAR SIGN
1413	0450	450	
1414	0410	410	
1415	0062	62	
1416	2100	2100	
1417	5476	5476	
1420	2421	2421	
1421	7700	7700	
1422	2221	2221	PLUS
1423	7500	7500	
1424	0461	461	
1425	6104	6104	
1426	7622	7622	

# CHARACTER TABLE



1427	6277	6277	
1430	7500	7500	A
1431	1006	1006	
1432	4546	4546	
1433	0023	23	
1434	4376	4376	
1435	2277	2277	
1436	7500	7500	B
1437	1004	1004	
1440	4462	4462	
1441	0006	06	
1442	4446	4446	
1443	7625	7625	
1444	7700	7700	
1445	2375	2375	C
1446	4610	4610	
1447	0676	676	
1450	2264	2264	
1451	7700	7700	
1452	7503	7503	D
1453	0203	203	
1454	0443	443	
1455	0243	243	
1456	5076	5076	
1457	2577	2577	
1460	2375	2375	E
1461	4604	4604	
1462	0400	400	
1463	6204	6204	
1464	0676	676	
1465	2264	2264	
1466	7700	7700	
1467	7500	7500	F
1470	0404	404	
1471	0062	62	
1472	0406	406	
1473	7622	7622	
1474	6477	6477	
1475	2324	2324	G
1476	7546	7546	

CHARACTER TABLE





1477	5006	5006	
1500	0343	343	
1501	7623	7623	
1502	4377	4377	
1503	7500	7500	H
1504	1000	1000	
1505	6206	6206	
1506	2200	2200	
1507	5076	5076	
1510	2277	2277	
1511	7504	7504	I
1512	0061	61	
1513	1061	1061	
1514	0004	04	
1515	7622	7622	
1516	6477	6477	
1517	0021	21	PERIOD
1520	7576	7576	
1521	2261	2261	
1522	7700	7700	
1523	0061	61	CLOSE
1524	7502	7502	
1525	1442	1442	
1526	7623	7623	
1527	6577	6577	
	0000		

END

CHARACTER TABLE



	0000		ORG	00	
0000	7011		JPI	ZESTA	NORM. START 3 CURVE
			REM		DISPLAY
0001	7012		JPI	1STA	DISPLAY NEXT N
			REM		CURVES, N IN A
0002	7013		JPI	2STA	DISPLAY NUMBER OF
			REM		CURVES IN A
			REM		STARTING AT CURVE 1
0003	7014		JPI	3STA	ADVANCE MAG TAPE
			REM		TO NEXT GRAPH
0004	7015		JPI	4STA	BACK MAG TAPE TO
			REM		PREVIOUS GRAPH
0005	7016		JPI	5STA	BACK MAG TAPE TO
			REM		PRESENT GRAPH
0006	7017		JPI	6STA	REWIND MAG TAPE
			REM		TO LOAD POINT
0007	7700		HLT		
0010	7013		JPI	2STA	
	0011	ZESTA	EQU	11	ENTRY ADDRESSES FOR
	0012	1STA	EQU	12	STARTING ROUTINE
	0013	2STA	EQU	13	
	0014	3STA	EQU	14	
	0015	4STA	EQU	15	
	0016	5STA	EQU	16	
	0017	6STA	EQU	17	
	0020	XPI	EQU	20	
	0021	YPI	EQU	21	
			REM		GRAPH REFERENCE
	0022	PA	EQU	22	POSITION, X AND
	0022	FI	EQU	22	Y ORDINATES
	0023	FE	EQU	23	BEGIN. OF GRAPH
			REM		POINT FILE
	0024	NOCUR	EQU	24	END OF GRAPH
	0025	IFTIL	EQU	25	POINT FILE
	0026	XPA	EQU	26	NO. OF CURVES DISPLAY
	0027	YPA	EQU	27	BEGIN. OF TITLE FILE
	0040	READA	EQU	40	TITLE LINE REFERENCE
	0041	LTRA	EQU	41	X AND Y ORDINATES
	0042	GRPA	EQU	42	LINK ADDRESSES FOR
	0043	TAPA	EQU	43	SUBROUTINES

LOW CORE LIST



0044	RNCA	EQU	44
0045	ROTA	EQU	45
0046	GREADA	EQU	46
0047	DA	EQU	47
0050	LDA	EQU	50
0060	XP	EQU	60
0061	YP	EQU	61
0062	P	EQU	62
0062	CP	EQU	62
0062	TP	EQU	62
0063	PH	EQU	63
0063	CH	EQU	63
0064	FP	EQU	64
0065	FPA	EQU	65
0066	FB	EQU	66
0067	TT	EQU	67
0070	ORIGS	EQU	70
0074	XOR	EQU	74
0075	YOR	EQU	75
0076	TLCC	EQU	76
0077	OB	EQU	77
0000		END	

TITLE LINE COORDINATE  
TRACKING CELLS  
FILE POINTER

FILE HALF WORD POINTER

FILE POINTER  
FILE POINTER  
FILE POINTER  
TEMPORARY  
ORIGIN SYMBOL  
ORIGIN COORDINATES

TITLE LINE COUNT  
OUTPUT BUFFER

LOW CORE LIST



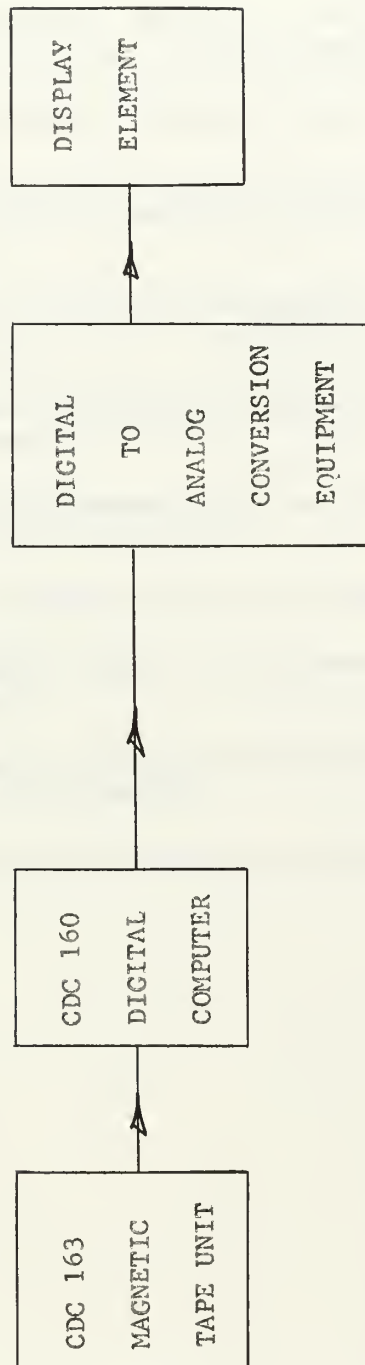


Fig. 1 Analog Display System





name	task
ZEST	Accepts and sequences the starting arguments set by the operator.
ROT	Controls the display sequence.
READ	Reads, transforms, and stores title and origin data from the magnetic tape unit. (Fixed location).
GREAD	Reads, transforms, and stores graph point data from the magnetic tape unit.
TAP	A general purpose read/write routine for the CDC 163 magnetic tape unit.
LTR	Outputs one line of BCD characters in a form appropriate for conversion by the D/A conversion equipment.
RNC	Reads six bit characters into the arithmetic register from the computer memory.
CHARAC. TABLE	Contains the movement codes for the generation of letters and symbols (fixed location).
GRP	Outputs the graph point file to the D/A conversion equipment.
DA	Delays computer action for approximately 6.5 milliseconds (unit delay).
LDA	Delays computer action for N unit delays, where N is an entry argument to the routine.

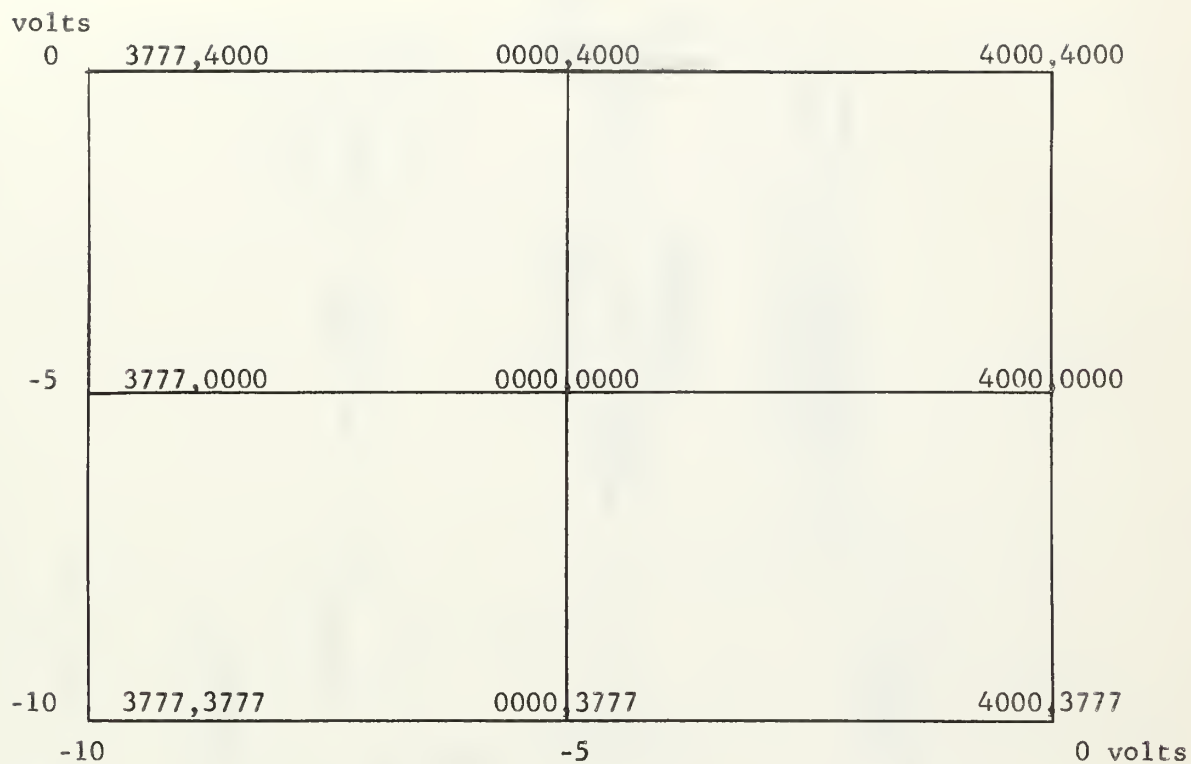
Figure 2. Tasks assigned to program routines.



Starting Address	Function
0000	Normal start for graph plot display. One curve and the scale grid is shown.
0001	Normal start for display of subsequent curves on a multiple curve graph.
0002	Normal start for display of a given number of curves from the beginning of a graph. The number of curves desired must be entered in the arithmetic register.
0003	Advances the magnetic tape to the beginning of the next graph plot. Halt in 0007.
0004	Backspaces the magnetic tape to the beginning of the previous graph plot. Halt in 0007.
0005	Backspaces the magnetic tape to the beginning of the present graph plot. Halt in 0007.
0006	Rewinds the magnetic tape to the load point. Halt in 0007.
0010	Same as 0002 start.

Figure 3. Starting addresses for the display program.





Voltage-Bit Pattern Comparison on Scope Face

bit pattern input	Voltage output
4000	0
7777	-5
0000	-5
3777	-10

Figure 4. Digital to analog conversion table and scope face diagram



















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An analog display system for digital gra



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